HERBICIDE EVALUATION STUDIES WITH

NUTSEDGE (*CYPERUS ROTUNDUS* L.)

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ABSTRACT

The herbicidal effectiveness of 16 chemicals on nutsedge control was studied at the Manoa Campus Farm and the Waimanalo Experiment Station. The studies consisted of five field experiments and two translocation greenhouse experiments which included C^{14}-labeled paraquat and MSMA. It was found that MSMA plus surfactant was the most promising herbicide to control nutsedge when compared to paraquat and aromatic oil. Five successive field applications of MSMA at 6#/A plus surfactant reduced the nutsedge population by 30% over a period of eight months at the Manoa Campus Farm. DSMA and DMAA showed a similar response to MSMA. Paraquat and aromatic oil applications did not result in a significant reduction of the nutsedge population. The time of application was an important factor in the activity of the herbicides. Morning and noon applications gave better control with MSMA than paraquat if subsequent regrowth populations were considered. Paraquat applied in the early evening was more effective than the morning or noon applications for short term control. However, at six weeks after application there were no differences in stand between the morning, noon and evening treatments with paraquat. Post-emergence applications of bromacil and D-732 were more effective than D-767 and amitrole. Dichlobenil gave the most satisfactory control among the preplant and preemergence herbicides. R-1856 resulted in slightly better control than EPTC; however, good control of nutsedge was found with EPTC at 6#/A for a period of 5 to 6 weeks. CP 50144, R-7465 and U-22,326 were not effective in controlling nutsedge under the test conditions.

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INTRODUCTION

Nutsedge is regarded as a serious weed pest in Hawaii as well as in other parts of the world. Its deep rhizomes and tubers, its ability to regenerate rapidly and also its tolerance to varying environmental conditions make the control of this weed very difficult. Smith and Fick (1937) found that a single nutsedge tuber produced a system of 146 tubers and basal bulbs in 3½ months in the greenhouse. Baker (1964) reported that a single nutsedge tuber planted in the field on 18-inch centers produced 180 tubers per square foot in four months to a depth of 6 inches. Nutsedge invades areas of principal economic crops of Hawaii, especially vegetables, fruit crops, sugar cane and pineapple. In Australia researchers at the Bureau of Sugar Cane Experiment Station (1964) found that the yield reduction of cane was related to decreasing soil moisture on plots infested with nutsedge. Nutsedge is not only competitive for moisture, but also for plant nutrients, light and other essentials for plant growth. In addition to the competition for moisture and nutrients, there is an added expense of removing the weed from cultivated areas. The appearance of beautiful lawns will be spoiled if invaded by nutsedge.

Attempts to control nutsedge have been underway for a long time. Hoeing seems to be a simple means of control, but the effect is very short-lived. Repeated plowing and drying, if the situation permits, is somewhat satisfactory. However, complete control will take a long time.

Smith and Mayton (1939 and 1942) and Davis and Hawkins (1943), concluded that frequent cultivation for two years was necessary for effective control of purple nutsedge. Day and Russell (1955) found that disking to a depth of 6 inches at intervals of three to four weeks without irrigation killed two-thirds of the tubers to a depth of 18 inches in 6 months. It can be assumed that cultural methods are not entirely practical for many situations because of the time element involved.

Chemical control is another approach to control nutsedge, and it appears to be one of the more promising methods at the present time. Leonard and Harris (1950), Bieske (1965), and Millard (1965) reported that methyl bromide is a compound which was proven effective and practical in eliminating smaller infestations, but it is not feasible for large areas because of high cost. Hauser (1963b), Chapman (1964), and Rochecouste (1965) showed that 2,4-D, especially in the amine or ester form, is another chemical shown to be effective against nutsedge. However, this chemical has limited use due to the hazardous nature of the spray drift onto many species of cultivated crops. In the 1960's some newer compounds were developed which showed selectivity in crops as well as nutsedge control.

The main purpose of this research was to evaluate the most promising recently-developed compounds for controlling nutsedge in horticultural crops. It is hoped that the trials will establish a foundation for future research on the control of nutsedge in horticultural crops. Emphasis was placed on the post-emergence removal of nutsedge with chemicals which may find use with fruit crops.

LITERATURE REVIEW

NUTSEDGE

Nutsedge (Cyperus rotundus L.), sometimes referred to as nutgrass, belongs to the family Cyperaceae. This perennial and troublesome cosmopolitan weed in gardens of many warm countries, has been known in Hawaii since 1850. It is difficult to eradicate because the rhizomes spread in the soil both horizontally and vertically to a depth of one foot or more; also it bears hard, black tubers which are less than 0.5 inches in length capable of producing new plants. According to Ramsdo and Burns (1925) the tuber is the primary reproductive structure of nutsedge which produces one or several rhizomes. The initial rhizome from a tuber is geotropically positive and grows upward through the soil surface where it develops a basal bulb. This basal bulb produces rhizomes which may develop into active basal bulbs or into dormant tubers. Berger and Day (1966) suggested that salicylic acid is the major mechanism associated with the seasonal dormancy of nutsedge tubers.

The plant looks much like a grass in that its leaves are smooth, narrow, and two to six inches in length. Two to four leafy bracts at the top of the stem surround three to eight unequal radiating flowering branches which are up to two and one half inches in length. The branches end in clusters of conspicuous, brown, narrow flower spikelets crowded with tiny flowers (Neal, 1965). Justice and Whitehead (1946) reported that the nutsedge plant apparently produces relatively few viable seeds. The plant multiplies itself mainly by

tubers, rhizomes, and basal bulbs, and the rapidity of multiplication is tremendous. Hauser (1962) reported that tubers of purple nutsedge planted at 1-foot intervals produced 3,090,000 plants and 4,420,000 tubers and bulbs per acre in 4 months, and at 3-foot intervals, 2,320,000 plants and 2,760,000 tubers and bulbs were produced, respectively. Hauser and Thompson (1959) also found that nutsedge tubers planted at 1-foot and 1-yard spacings in sterilized soil produced 71 and 49 plants per square foot, respectively, after 10 weeks.

GENERAL BIOLOGICAL PROPERTIES OF HERBICIDES

Long et al. (1962) reported that methanearsonates were effective in controlling nutsedge. They found that repeated applications of amine methyl arsonate (AMA) over a two year period resulted in significant reductions of nutsedge tubers at rates of 1.3, 2.6, and 3.8 ounces per 1,000 sq. ft. Single annual applications of this compound at the same rates were ineffective. In 1965 monosodium methanearsonate (MSMA) and disodium methanearsonate (DSMA) became popular. Researchers at Vineland Chemical Company (1965) showed that in combination with diuron, MSMA and DSMA are effective as a post-emergence treatment for cotton at least 6 inches tall; and these compounds applied 4 to 5 times to Johnsongrass (Sorghum halepense) on uncropped ground nearly eliminated the rhizomes. Widiger (1966) reported that MSMA and DSMA can control more than 30 weed species; among these are Sorghum halepense, Cyperus rotundus, Cyperus esculentus, Paspalum dilatatum, Paspalum conjugatum,

Cenchrus echinatus, and Cenchrus pauciflorus. He stated that according to tests conducted by The Ansul Company with Johnsongrass, the best results are obtained when these herbicides are applied during conditions of high temperatures and clear, sunny skies. Kempen (1966) found that DSMA and MSMA at the 4 pound/acre rate gave superior Johnsongrass control when 4 applications were made at 3 to 5 week intervals. Elmore et al. (1966) worked with MSMA at the same rates, same number of applications, but at 4 week intervals with similar results. Anderson et al. (1966) found that applications of MSMA to nutsedge at the rate of 10,000 micrograms per plant resulted in 100 per cent top kill of the original plant without regrowth four months later. At the same concentration DSMA produced 100 per cent top kill, but some regrowth was evident. MSMA and DSMA are registered by the Federal Food and Drug Administration for use in cotton and registration for the use of MSMA in citrus and grape vineyards is still pending.

Paraquat, another compound of interest for nutsedge control, is a contact systemic herbicide. It is rapidly absorbed by the foliage and kills the plant by interfering with the process of photosynthesis. Temperature does have an effect on rapidity of phytotoxicity. Bovey and Davis (1966) found that at lower temperatures the rapidity of plant kill (2 days after treatment) was retarded with most species tested. However, after 1 week, there was usually little difference on plants grown at either high or low temperatures. Both broadleaves and grasses are controlled, but paraquat is more effective on grasses. Paraquat is quickly inactivated upon contact with the soil and it is

absorbed into the plant foliage within minutes after application. Brown well-developed bark of trees and shrubs is a barrier to the entry of paraquat, hence it is relatively safe to spray onto the stem and trunks of established woody species. Any green tissue, however, will be damaged by paraquat if the spray is allowed to contact the tissues. Condron (1967) reported that paraquat is registered in the U.S.A. for noncrop usage, cotton, non-bearing fruit trees and vines, and as a potato top-killer.

Eptam (EPTC) has been known as a pre-emergence herbicide on many crops and it is toxic to several weeds (Stauffer Chemical Company, 1956). Tests for several years showed that the chemical has proven to be a very versatile and effective weed killer. Since this compound breaks down rapidly in moist soil to produce a volatile vapor, it is best to apply EPTC to the soil surface and immediately incorporate it into the soil. Nutsedge is a weed which is susceptible to this chemical. Crabtree (1962) reported that EPTC at 2.5 pounds active/acre gave over 97% control of nutsedge with no injury to established asparagus plantings. Romanowski and Tanaka (1965) showed that EPTC provided nutsedge control in Hawaii and recommended its use for weed control in snapbeans. Holt etal. (1962) in a nutsedge trial with EPTC showed that granular EPTC was more effective than the emulsifiable formulation in reducing tuber germination; also, emulsifiable formulations gave significantly better control when incorporated mechanically than by means of incorporation with sprinkler irrigation. He indicated that repeat applications of EPTC were significantly better in terms of tubers killed than single

applications of the same rate of the herbicide. Nocombe (1961) found that shoot density 36 weeks after the first treatment was reduced by about 75 per cent in the plots treated with 8 pounds active/acre of the granular formulation under very dry conditions. Further tests by him indicated that neither young nor mature coffee trees are affected by EPTC up to 8 pounds/acre. Gray (1966) showed that a single drop of either EPTC technical + 25% oil or EPTC 6-E formulation placed into the center whorl of leaves of a nutsedge plant resulted in complete kill.

Recently, it was found that there are a few more chemicals which are effective against nutsedge. Waters and Burgis (1965) reported that the most promising soil incorporated treatments included dichlobenil, TH-073 composition not specified at 20 pounds/acre, and DuPont 732 and DuPont 733 at 10 pounds/acre. However, no maize, squash, or gladiolus cormels could be grown in the treated soil even 6 months after application. At the same time it was found that EPTC at 5 pounds/acre prevented nutsedge emergence for 2 months; and crops could be grown in the treated soil 30 days after treatment. Sasser and Locasio (1966) reported that good to excellent results were obtained with 12 pounds/acre of EPTC, dichlobenil, and TH 073-H. No injury to bean and cucumber plants were observed after 6 months with EPTC, but injury was incurred with dichlobenil and TH 073-H. EPTC is registered for use by the Federal Food and Drug Administration in the United States for beans (dry, snap, and pole), corn (field, sweet), carrots, peas (green processing), pineapples, potatoes, and strawberries.

R-7465 and R-1856 are other herbicides produced by the Stauffer Chemical Company. R-7465 was found to be highly active on a broad spectrum of weed species and exhibited some selectivity in tomatoes and green beans. R-1856 is non-toxic to tomatoes and squash. Romanowski et al. (1966) showed that both chemicals are effective against nutsedge and some grasses, but poor control of broadleaved weeds was obtained. Gray et al. (1961) found that a soil incorporated preplant application of R-1856 at 3 to 5 pounds/acre gave good control of many grasses including Johnsongrass and nutsedge. Crops tolerant to this compound were cucumbers, cantaloups, and tomatoes.

According to researchers at the Monsanto Chemical Company, CP50144 is another pre-emergence herbicide which shows excellent control of many weed species, but its phytotoxicity to some crop plants is relatively high. However, it has been reported to control nutsedge and shows some selectivity in crucifers and large seeded legumes.

Amitrole is another chemical which is toxic to nutsedge. Hauser (1963a) indicated that amitrole was generally very toxic in young nutsedge systems, especially when applied 4 weeks after emergence. Such treatments caused uniform chlorosis and death of many rhizomes and bulbs. The next most susceptible stages were at 1 or 2 weeks after emergence when chlorosis was severe and recovery slow. Some resistance to amitrole appeared to develop six weeks after emergence and applications at 10 weeks after emergence were ineffective. Hauser (1963b) also found that five applications of amitrole or nine of 2,4-D during a 2-year period, combined with disking and competition

from a vigorously growing crop, gave good control of purple nutsedge, provided the initial treatment was made shortly after emergence each year and before the plants began to produce dormant tubers.

Hilton (1964) reported that of all the DuPont uracils tested in Hawaii bromacil, D-732, D-766, and D-767 showed a good degree of control of either purple or yellow species of nutsedge. A trial in Trinidad (1964) showed that D-732 and D-767 at 3 and 4 pounds/acre resulted in some inhibition of germination and growth, but all provided good weed control for up to 59 days after treatment. Hilton (1965) reported that from a total of 8 substituted uracils tested since 1961, D-767 and D-732 have emerged as probably the best candidates for sugar cane in Hawaii and other areas as well. Their effectiveness, as pre-emergence herbicides, on the broad spectrum of seeding grasses and broadleaves were favorable where they were compared with the standard herbicide diuron. Stamper (1966) and Millhollon (1967) indicated that D-732 (Terbacil) is the best uracil for cane because it is both relatively non-toxic to sugar cane and provides effective weed control. D-732 has also been used in citrus (Ryan, 1965) and peach (Price, 1966) experiments without toxicity to the trees. Recently D-732 was registered for use in the U.S.A. for sugar cane, apple, peach, and citrus (grapefruit, orange and lemon).

Morey and Schmidt (1963) reported that bromacil is highly effective against nutsedge and other weeds. In established citrus, Ryan (1965) reported that bromacil at 3 and 6 pounds/acre applied 3 times over a period of 14 months gave fair to good control of Panicum repens under 5-year old Valencia orange trees on rough lemon rootstocks

and produced no more than temporary foliar injury to the trees.

UPTAKE AND TRANSLOCATION OF HERBICIDES

Slade and Bell (1966) researched with tomato plants and showed that paraquat moves in the xylem with the transpiration stream. There was an enhancement of the amount of paraquat transported from the treated leaves which occurred when treated plants were kept in darkness for a period following treatment and then exposed to light. This is possibly due to the greater movement into the xylem through undamaged tissue which can occur in the dark. Once the chemical has been absorbed into treated leaves, light induced damage is required for significant movement through the rest of the plant to take place, but the damage then inhibits further entry of paraquat into the xylem. Coats et al. (1965) showed that in wheat appreciable movement of paraquat occurred, including some movement into the roots, but translocation was not appreciably affected by placing the plants in the dark for 12 hours after treatment. There might be differences in the movement of paraquat in different species, as Thrower et al. (1965) suggested with diquat. Slade and Bell (1966) found that in broadbean the enhancement of movement was very much less pronounced than in tomato. Wood and Gosnell (1966) reported that the extent of translocation was much greater when 24 hours of darkness followed treatment in darkness than when the treatment was applied during day time. Brian (1966) indicated that the biological activity of diquat and paraquat was increased by an increase in environmental humidity, and this improved activity resulted from an increase in both uptake

and movement. Clor et al. (1962) found that high humidity increased transport in both starved and non-starved plants, and in 1963 they reported that low humidity suppressed the entry of 2,4-D, EPTC, and some other leaf sprays.

Connlley and Kahn (1961) reported that the absorption and translocation of EPTC by both nutsedge tubers (C. esculentus) and potato roots were rapid following a root application. EPTC did not enter germinating tubers, but did enter germinating potato seed pieces especially through the cut surface. Foliar application showed that EPTC translocated acropetally to a considerable degree, and translocation basipetally was very slight. Amitrole translocated acropetally and basipetally in appreciable amounts and accumulated in the tubers resulting in reduced viability. Hill et al. (1963) found that the most effective point of application, to study the effect of amitrole on seed germination, appeared to be just below the umbel. He also showed that seed germination was significantly reduced following application.

Rumburg et al. (1960) using As^{76} demonstrated the translocation patterns of arsenic (As) in crabgrass and soybeans. Mobility was influenced by chemical formulation, temperature and species. Arsenic applied as disodium methylarsonate, As^{76} (DSMA) was more mobile than As applied as sodium arsenite As^{76}. He found that the greater movement of arsenic (DSMA-As^{76}) at higher temperatures resulted in more phytotoxicity to the crabgrass. However, there is no consistent trend concerning the effect of temperature on phytotoxicity in As applied as cacodylic acid and sodium arsenite. Holt et al. (1966) in

his study with purple nutsedge demonstrated that As in the amine methyl arsonate (AMA) form was translocated laterally to tubers separated by at least four tubers from the treated shoot. The tubers on the opposite end of the chain from the treated shoot tended to be higher in As content than the middle tubers, and translocated As tended to be higher in tubers from which active growth was present or developed.

METABOLISM AND PHYTOTOXICITY OF HERBICIDES

There are two possible modes of action of paraquat. Calderbank (1964) theorized that the toxic effects of paraquat are exerted by virtue of its reduction to the corresponding stable free radical. The free radical subsequently reacts with O_2, regenerating paraquat and giving rise to the peroxide radical or H_2O_2, which is considered to be the actual phytotoxic agent. Paraquat can be reduced in the chloroplast system, and the free radical is formed under this condition. Boon (1964) suggests that the reduction of the herbicide to the free radical followed by reoxidation could be considered as shunting the energy generated in the primary stages of photosynthesis away from the production of the end product. TPNH (NADPH) which is essential for the fixation of carbon is not formed, and instead a free radical (reduced form of paraquat) is produced and subsequently reoxidized. However, the ultimate proof of the presence of free radicals or hydrogen peroxide in the green plant is still lacking.

Slade (1965, 1966) reported that the degradation of paraquat was caused by photochemical decomposition on the surface of the leaves of

the plants and not by metabolism. He found two degradation products, namely, 4-carboxy-1-(methyl ^{14}C)-pyridinium chloride and methylamine-^{14}C hydrochloride. The degradation was not observed in the dark, and only occurred to a significant extent in daylight in the summer. When paraquat was applied to the tops of potatoes, there was no evidence of the presence of photochemical decomposition products in the tubers.

MATERIALS AND METHODS

FIELD EXPERIMENTS

The effectiveness of several herbicides on nutsedge control was evaluated at the Manoa Campus Farm and the Waimanalo Experimental Farm (Table I). The experiments consisted of evaluating post-emergence herbicides (Experiments 1, 2, 3, and 4) and preplant or preemergence herbicides (Experiment 5). The nutsedge which was used in the experiments at the Manoa Campus was field planted on April 20, 1966. The naturally occuring nutsedge was used at the Waimanalo Experimental Farm.

Experiment 1 which was conducted at the Manoa Campus Farm contained four contact herbicides and a non-treated check which were arranged in a randomized complete block with three replications and a plot size of 10 feet by 10 feet. The treatments were as follows: 55AR aromatic oil, paraquat, MSMA and DSMA. Paraquat, MSMA, and DSMA were mixed with X-77 surfactant at the rate of .2% by volume. The chemicals were applied with the use of a one-gallon sprayer equipped with a 11006 T-jet nozzle discharging 80 gpa (gallon per acre) at a pressure of 25 psi (pounds per square inch). The herbicides were applied on August 5, August 30, and October 4, 1966. The weeds other than nutsedge were removed on January 20, 1967 by applying linuron at 4 lbs active/A plus .2% X-77. Standard weed counts and/or ratings were made from time to time to determine the effectiveness of the herbicides. The number of weeds per square foot is an average of two counts per plot. The experimental observations indicated that the

time of application had some effect on the degree of chemical phytotoxicity, hence for subsequent applications the design of the experiment was altered. Each original plot was divided in half and two subtreatments were added. The subtreatments consisted of applying the same chemicals at two different times of day, namely, at 1:00 to 2:00 PM and again at 5:00 to 6:00 PM. The herbicide concentration and volume per acre remained the same; however, the aromatic oil treatments were considered as the checks. The split applications were made on November 21, 1966 and February 13, 1967.

Experiment 2 was conducted at the Waimanalo Experimental Farm and it was similar to the latter part of Experiment 1. The treatments were arranged in a randomized split plot design with 4 main plots which were replicated 4 times. The main plots consisted of paraquat, MSMA, DSMA, and aromatic oil. Each main plot was divided into 3 subplots (10 feet x 10 feet) which consisted of differing times of application. The times of application were in the morning (8:00 to 9:00 AM), noon (1:00 to 2:00 PM) and in the evening (5:00 to 6:00 PM). The method of application, rates used and evaluations were the same as in Experiment 1. The application of the herbicides was made on October 13, November 13, 1966, January 26, and March 31, 1967. Undesirable weeds were removed by hand hoeing from time to time.

Experiment 3 was used to evaluate 4 post-emergence herbicides at the Manoa Campus Farm. The treatments included DuPont 732, DuPont 767, bromacil, amitrole + .2% X-77, and aromatic oil as a check. A randomized complete block design was used with 3 replications and a plot size of 10 feet by 10 feet. The treatments were made on August

5, October 4, November 20, 1966 and March 3, 1967.

Experiment 4 was similar to Experiment 3, but it was conducted at the Waimanalo Experimental Farm. The same design and herbicides were used as in Experiment 3; however, the number of replications were increased to four. The treatments were applied on December 31, 1966 and February 20, 1967.

Experiment 5 was used to evaluate some pre-emergence and soil-incorporated herbicides at the Manoa Campus Farm. A randomized complete block design was used with 3 replications and a plot size of 10 feet by 10 feet. EPTC, R-7465, R-1856, dichlobenil, U-22,326, and CP 50144 were tested. This experiment required soil tillivation about 5 inches deep before treatment. EPTC, R-7465, R-1856, and dichlobenil were tillivated into the soil with a motor driven hand tillivator immediately after applications; whereas CP 50144 and U-22,326 were not soil incorporated. Applications were made 2 days after tillivation of the plots on August 5, August 30, 1966 (R-7465, dichlobenil, CP 50144), October 4, 1966 (EPTC, R-1856), and February 22, 1967 (EPTC, R-1856, dichlobenil, CP 50144, and U-22,326). The sprays were applied at 80 gallons of spray mix per acre with a 1 gallon sprayer.

TRANSLOCATION STUDIES IN THE GREENHOUSE

An experiment was conducted to study the translocation of C^{14}-paraquat at 6, 12, 24 and 48 hours after a leaf application. A second experiment was initiated to study the translocation of C^{14}-paraquat and C^{14}-MSMA at 2, 4, 8 and 16 days after leaf treatment.

The short term C^{14}-paraquat study will be referred to as Experiment 6 and the C^{14}-paraquat and C^{14}-MSMA study as Experiment 7.

The nutsedge tubers were germinated in a sand medium for 12 days and then transplanted into full strength Hoagland's solution No. 1 (Hoagland and Arnon, 1950) and placed in a greenhouse for 3 to 4 weeks before treatment. C^{14}-paraquat (specific activity .01 $\mu c/\mu l$ and intensity of beta ray emission approximately 27,000 cpm/5 μl) and C^{14}-MSMA (specific activity about .002 $\mu c/\mu l$ and intensity 9,900 cpm/5 μl) were used in the experiment. The concentration of C^{14}-paraquat used in this study was about 1,300 ppm which was very close to the 1,500 ppm concentration of paraquat used in the field. C^{14}-MSMA concentration used in the greenhouse study was about 18,000 ppm which was double the concentration used in the field. Since the specific activity of this compound was very low, the concentration was not decreased to that used in field. Five μls of the solution were mixed with X-77 (0.2% v/v) and placed within a lanolin ring on the 5th leaf of the plant. Applications were made in the morning (9:00 AM), noon (1:00 PM), and evening (5:00 PM) on March 1, 1967 for Experiment 6, and on March 26 for Experiment 7. After harvesting at the desired time intervals the plants were frozen overnight and then freeze-dried for one day (Experiment 6) and two days (Experiment 7). A Sublimator Automatic Freeze-drier was used to dry the nutsedge plants at a temperature of 0 to 5°F. After freeze-drying the plants were pressed overnight, and exposed to x-ray film for one week (paraquat treatment) and 2 weeks (MSMA treatment). The process of autoradiography was done according to the method described by Craft

and Yamaguchi (1964).

STATISTICAL METHODS

Analysis of variance was used to determine the significance of treatment effects in the herbicide phytotoxicity study (Experiments 2, 3, 4 and 5) and D test devised by Tukey (1953) was used to determine if the treatment means were significantly different. All tables of analysis of variance are contained in the appendix.

TABLE I. LIST OF HERBICIDES EVALUATED UNDER FIELD CONDITIONS

Trade Name[1/]	Supplier[2/]	Temporary Designation or Common Name	Chemical Name
Amino triazole	A	amitrole	3-amino-1,2,4-triazole
Ansar 170	B	MSMA	monosodium acid methanearsonate
Ansar 184	B	DSMA	disodium acid methanearsonate
Ansar 529	B	MSMA	monosodium acid methanearsonate plus surfactant
Aromatic Oil 55AR	C		
Casoron	D	dichlobenil	2,6-dichlorobenzonitrile
	E	CP 50144	Not disclosed
	F	D-767	Uracil compound
Eptam	G	EPTC	ethyl N,N-di-n-propylthiolcarbamate
Hyvar X	F	bromacil	5-bromo-3-sec-butyl-6-methyluracil
Phytar 560	B	DMAA	dimethylarsinic(cacodylic) acid
Paraquat	H	paraquat	1,1'-dimethyl-4,4'-dipyridylium cation
	G	R-1856	t-butyl di-n-propylthiolcarbamate
	C	R-7465	2-(α-naphtoxy)-N,N-diethyl propionamide

TABLE I. (Continued) LIST OF HERBICIDES EVALUATED UNDER FIELD CONDITIONS

Trade Name[1/]	Supplier[2/]	Temporary Designation or Common Name	Chemical Name
Terbacil	F	D-732, sinbar	3-tert-butyl-5-chloro-6-methyluracil
	I	U-22,326	2-(4-chloro-2-methylphenoxy)-propionanilid
Multi-Film X-77	J	Non-ionic Spreader Activator	Alkylarylpolyoxyethylene glycols, free fatty acids and isopropanol

[1/] Active ingredients of chemical formulations: Emulsifiable concentrate (pounds per gallon) - Ansar 170 6.6 lbs; Ansar 529 4.0 lbs; CP 50144 4 lbs; Eptam 6 lbs; Paraquat 2 lbs; Phytar 560 2.48 lbs; and R-1856 6 lbs. Wettable powders - Amino triazole 50%; Ansar 184 50%; Casoron 50%; D-767 80%; Hyvar-X 80%; R-7465; Terbacil 80%; and U-22,326 50%.

[2/] Principal supplier of the herbicide: A = Amchem Products, Inc.; B = The Ansul Company; C = Standard Oil Company; D = Thompson-Hayward Chemical Company; E = Monsanto Chemical Company; F = DuPont du Nemours Company; G = Stauffer Chemical Company; H = Chevron Chemical Company; I = Upjohn Company; J = Colloidal Products Corporation.

RESULTS

The results for the 5 experiments which were conducted under field conditions will be presented in the first part of this section.

FIELD EXPERIMENTS

Experiment No. 1a and 1b

The first experiment was exploratory in nature to determine the comparative effectiveness of four contact herbicides on nutsedge control.

On August 19 (2 weeks after treatment) MSMA plus surfactant resulted in better nutsedge control than aromatic oil which already showed evidence of regrowth (Table I.1).

TABLE I.1. NUTSEDGE RESPONSE TO CONTACT HERBICIDES, MANOA CAMPUS FARM, EXPERIMENT NO. 1a[1/]

Treatment lbs active/acre	No. of plants per square foot 1st application 14 da[2/] (Aug. 19)	3rd application 35 da (Nov. 8)
1. Check non-treated	45.3	59.0
2. Aromatic Oil 55AR 80 gpa	35.7	48.7
3. MSMA 6# + X-77 .2%(v/v)	23.3	58.0
4. DSMA 6# "	28.7	61.7
5. Paraquat 1# + "	30.3	55.0
D (5% level)	9.77	7.82

[1/]Applications were made on Aug. 5, Aug. 30 and Oct. 4, 1966, respectively.

[2/]No. of days after application.

MSMA and DSMA produced maximum control about 10 days after treatment in contrast to aromatic oil which showed maximum control in 4 to 5 days. However, at 5 weeks after the second treatment aromatic oil turned out to be slightly better than MSMA, DSMA and paraquat; nevertheless none of the treatments produced effective control.

Preliminary observations from the Waimanalo Experiment Station implied that the time of application during the day had some influence on the activity of the arsonates and paraquat. Hence, the plots in Experiment 1b were divided into noon and evening applications. The experimental results contained in Table I.2 were largely exploratory and observational; therefore no statistical comparisons were made between the treatment means.

TABLE I.2. EFFECTS OF TIME OF APPLICATION TO NUTSEDGE RESPONSE TO THE HERBICIDES, MANOA CAMPUS FARM, EXPERIMENT NO. 1b[1/]

Treatment lbs active/acre	No. of plants per square foot			
	1st application		2nd application	
	26 da[2/] (Dec. 17)	76 da (Feb. 5)	20 da (Mar. 5)	48 da (Apr. 2)
1. Check non-treated	68.7	76.0	85.7	92.3
2. Check (Aromatic oil 55AR 80 gpa)				
Noon (1:00-2:00 PM)	30.7	90.7	59.7	86.0
Evening (5:00-6:00 PM)	26.7	84.3	52.0	78.0
3. MSMA 6# + X-77 .2%				
Noon	35.0	86.3	39.0	57.7
Evening	39.0	77.0	53.7	80.0
4. DSMA 6# + X-77 .2%				
Noon	32.3	82.3	36.0	58.0
Evening	38.0	81.0	50.0	80.3
5. Paraquat 1# + X-77 .2%				
Noon	17.3	96.3	44.7	90.3
Evening	11.3	81.6	22.0	80.3

[1/]Applications were made on Nov. 21, 1966 and Feb. 13, 1967.

[2/]No. of days after application.

It can be seen that on December 17 paraquat exhibited better control than the two arsonates. Paraquat applied in the evening resulted in nutsedge control superior to the noon treatment. On the contrary, the noon applications appeared to be more effective than the evening applications when the results for the arsonates are considered. The younger shoots or the young plants were more responsive than the older ones. Besides, it was found that with garden spurge (Euphorbia hirta) and niruri (Phyllanthus niruri) only the upper portion of the weeds were injured in the evening treatments with arsonates and regrowth developed early as compared to more complete kill in the noon applications. The effectiveness of the chemicals lasted for approximately 4 to 5 weeks. It appeared that after continuous treatment applications, the arsonates were slightly more effective than paraquat in reducing the nutsedge population.

The effects of the treatments may not have been just top kill but also destruction of the tubers. Investigations were made to see if some of the tubers were killed. The method used was to remove soil samples to a depth of 3-4 inches in each plot of MSMA, paraquat, and aromatic oil. The dead and live tubers and bulbs were counted. The average per cent of dead tubers (3 counts per plot) for MSMA, paraquat, and aromatic oil was 52, 12, and 10%, respectively.

Experiment No. 2a and 2b

This experiment was conducted at the Waimanalo Experiment Station primarily to study the phytotoxicity of contact herbicides in relation to the time effect.

TABLE II.1. NUTSEDGE RESPONSE TO HERBICIDES APPLIED AT DIFFERENT TIMES OF THE DAY, WAIMANALO EXPERIMENT STATION, EXPERIMENT NO. 2a[1/]

Treatment lbs active/acre	No. of plants per square foot			
	1st application		2nd application	
	11 da[2/] (Oct. 24)	25 da (Nov. 7)	9 da (Nov. 22)	73 da (Jan. 25)
1. Check (Aromatic Oil 55AR 80 gpa)				
Morning (8-9 AM)	21.0	31.8	26.8	38.5
Noon (1-2 PM)	20.5	31.3	21.0	41.0
Evening (5-6 PM)	17.8	30.0	25.3	40.5
2. MSMA 6# + X-77 .2% (v/v)				
Morning	15.8	15.0	13.3	24.8
Noon	14.8	20.0	12.5	26.5
Evening	13.3	18.8	17.0	28.5
3. DSMA 6# + X-77 .2% (v/v)				
Morning	20.3	23.8	23.8	35.8
Noon	19.5	29.3	25.3	35.3
Evening	17.3	25.3	22.3	36.3
4. Paraquat 1# + X-77 .2% (v/v)				
Morning	18.0	25.8	23.3	35.5
Noon	15.5	25.8	19.5	33.8
Evening	4.3	15.5	10.8	35.3
D(5% level)	4.97	ns	7.18	ns

[1/]Applications made on Oct. 13 and Nov. 13, 1966, respectively.

[2/]No. of days after application.

The results show that paraquat applied in the evening gave the best control at 2 to 3 weeks after application when the regrowth appearance was considered. Another interesting observation is that the control experienced with MSMA was not influenced by the time of application. In general MSMA looked better than any treatment in the field when the long term effects are considered. DSMA was the least active of the compounds when compared to the check aromatic oil.

FIGURE 1. MSMA (FRONT) AND OIL (BACK), 3 WEEKS AFTER LAST APPLICATION, EXPERIMENT NO. 2b (PHOTOGRAPH TAKEN ON APRIL 22, 1967)

Because DSMA was ineffective it was replaced by another arsonate compound dimethylarsinic acid (DMAA) in Experiment 2b. Also, word was received that Ansar 529 (MSMA plus a commercial surfactant) was being considered for possible registration in citrus by mainland U.S.

Agricultural Experiment Stations. With these two new developments, substitutions were made for treatments 2 and 3 and the results are contained in Table II.2.

TABLE II.2. NUTSEDGE RESPONSE TO HERBICIDES APPLIED AT DIFFERENT TIMES OF THE DAY, WAIMANALO EXPERIMENT STATION, EXPERIMENT NO. 2b[1/]

Treatment lbs active/acre	No. of plants per square foot		
	1st application		2nd application
	25 da[2/] (Feb. 20)	64 da (Mar. 31)	30 da (Apr. 30)
1. Check (Aromatic Oil 55AR 80 gpa)			
Morning (8-9 AM)	48.8	55.3	55.0
Noon (1-2 PM)	46.8	56.3	57.0
Evening (5-6 PM)	48.3	54.0	57.8
2. MSMA 6#			
Morning	22.3	28.0	21.0
Noon	21.5	31.0	24.3
Evening	27.8	42.0	44.3
3. DSMA 6#			
Morning	20.5	34.0	26.8
Noon	32.8	46.5	39.5
Evening	33.0	53.3	52.3
4. Paraquat 1 + X-77 .2% (v/v)			
Morning	39.8	53.8	49.3
Noon	28.5	51.0	46.0
Evening	14.3	42.3	30.0
D(5% level)	11.54	12.80	15.34

[1/] Applications made on Jan. 26 and Mar. 31, 1967, respectively.

[2/] No. of days after application.

It was found that DMAA produced a degree of control almost as effective as MSMA. Another interesting observation is that both MSMA and DMAA were consistently more effective when applied in the morning.

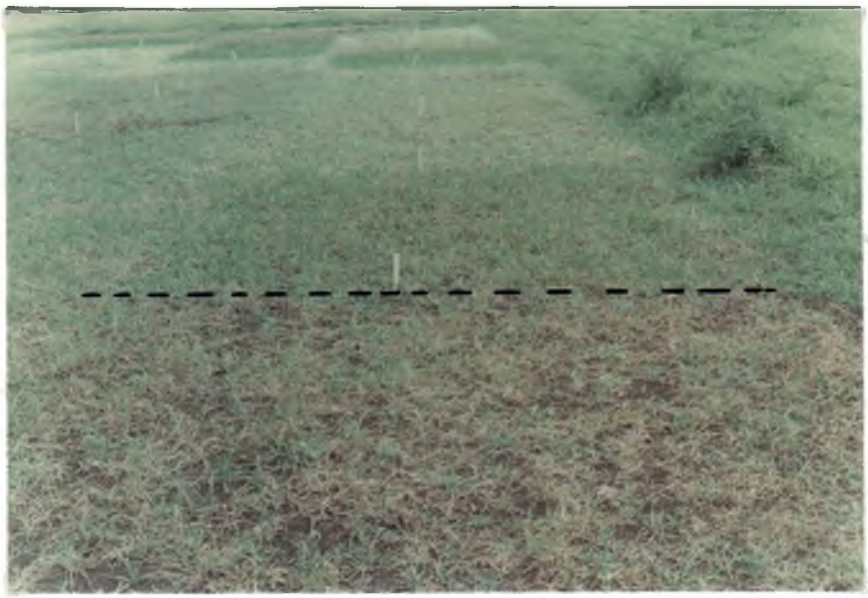

FIGURE 2. DMAA NOON (FRONT) AND EVENING (BACK), 3 WEEKS AFTER LAST APPLICATION, EXPERIMENT NO. 2b (PHOTOGRAPH TAKEN ON APRIL 22, 1967)

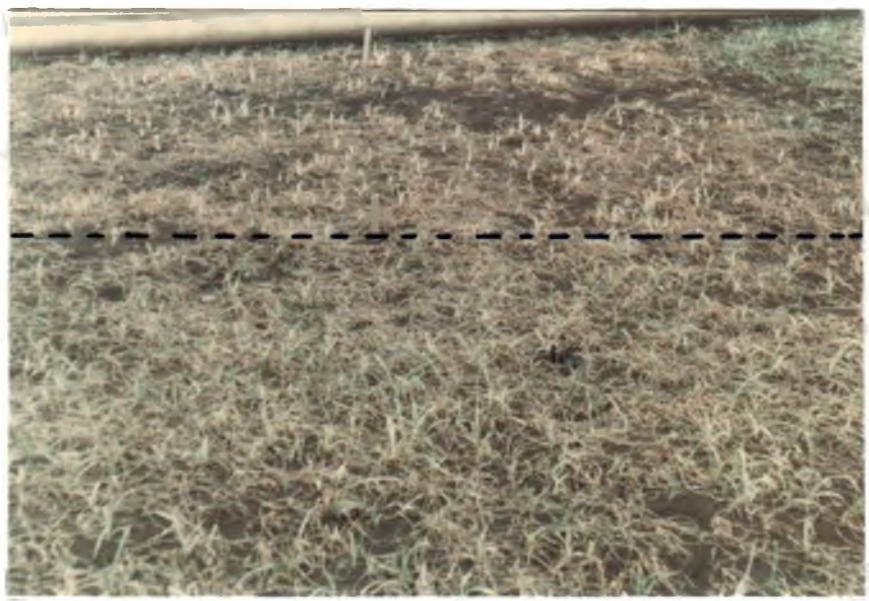

FIGURE 3. PARAQUAT NOON (FRONT) AND EVENING APPLICATION (BACK) 1 WEEK AFTER TREATMENT, EXPERIMENT NO. 2a (PHOTOGRAPH TAKEN ON OCTOBER 20, 1966)

The combined overall main effects for Experiment 2a and 2b are presented in Tables II.3 and II.4.

TABLE II.3. MAIN EFFECTS FOR NUTSEDGE RESPONSE TO HERBICIDES, EXPERIMENT NO. 2a AND 2b[1/]

Treatment lbs active/acre	Oct 24 11 da[2/]	Nov 7 25 da	Nov 22 9 da	Jan 25 73 da	Feb 20 25 da	Mar 31 64 da	Apr 30 30 da
1. Check (Aromatic Oil 55 AR 80 gpa)	59.3	93.0	73.0	120.0	143.8	165.5	169.8
2. MSMA 6# + surfactant	43.8	53.8	42.8	79.8	71.5	101.0	89.5
3. DSMA 6# + surfactant	57.0	78.3	71.3	107.3	--	--	--
4. DMAA 6# + surfactant	--	--	--	--	86.3	133.8	118.5
5. Paraquat 1# + surfactant	37.8	67.0	53.5	102.0	82.5	147.3	125.3
B(5% level)	7.66	n.s.	n.s.	n.s.	15.21	21.37	22.8

[1/]Applications made on Oct. 13, Nov. 13, 1966, Jan. 26, and Mar. 31, 1967.

[2/]No. of days after last treatments.

Since all the chemicals are contact herbicides the true differences are distinguishable only for short periods of time. However, MSMA was shown to be more phytotoxic to nutsedge than paraquat or aromatic oil in the final evaluation of the experiment (Table II.3). DMAA might have been better than paraquat if it had been applied successively from the beginning. One of the more interesting observations was that the nutsedge population increased with the continual use of the herbicides, especially aromatic oil.

TABLE II.4. MAIN EFFECTS FOR TIME OF DAY APPLICATIONS ON NUTSEDGE RESPONSE, EXPERIMENT NO. 2a AND 2b[1/]

Application	No. of plants per square foot						
	Oct 24 11 da[2/]	Nov 7 25 da	Nov 22 9 da	Jan 25 73 da	Feb 20 25 da	Mar 31 64 da	Apr 30 30 da
Morning (8:00-9:00 AM)	18.8	24.1	21.8	33.6	32.8	43.8	38.0
Noon (1:00-2:00 PM)	17.6	26.6	19.6	34.1	32.4	46.2	41.7
Evening (5:00-6:00 PM)	13.1	23.0	18.8	34.5	30.8	47.9	46.0
D(5% level)	2.8	n.s.	2.39	n.s.	n.s.	n.s.	5.12

[1/]Applications made on Oct. 13, 1966, Jan. 26 and Mar. 31, 1967.

[2/]No. of days after last treatment.

Except for the Oct. 24, Nov. 22, and Apr. 30 evaluation dates the overall main effects for time of application were not significant (Table II.4). Furthermore, the data contained in Table II.4 are of questionable value because of the interaction shown in the analysis of variance contained in Appendix Table II.1 to II.7.

Experiment No. 3

Experiment No. 3 was initiated at the Manoa Campus Farm to evaluate the effectiveness of post-emergence translocated herbicides.

TABLE III. RESPONSE OF POST-EMERGENCE HERBICIDES TO NUTSEDGE, MANOA CAMPUS FARM, EXPERIMENT NO. 3[1/]

Treatment lbs active/acre	No. of plants per square foot		
	2nd application 35 da[2/] (Nov. 8)	3rd application 78 da (Feb. 5)	4th application 58 da (Apr. 30)
1. Aromatic Oil 55AR 80 gpa	44.7	91.0	92.7[3/]
2. D-732 4#	32.7	20.7	12.0
3. D-767 4#	28.0	34.7	24.3
4. Bromacil 2#	33.7	40.0	24.0
5. Bromacil 4#	26.3	14.3	4.0
6. Amitrole 8# + X-77 .2% (v/v)	38.0	56.7	69.7
D(5% level)	13.60	24.55	12.7

[1/] Herbicides applied on Aug. 5, Oct. 4, Nov. 20, 1966, and Mar. 3, 1967, respectively.

[2/] No. of days after treatment.

[3/] Aromatic oil 76 days after treatment.

From the observations the uracil compounds (D-732, D-767, and bromacil) produced necrotic chlorosis about 3 weeks after treatment and some lethal effects resulted only after the second application was made. Chlorotic leaf injury was exhibited about 10 days after treatment with amitrole and the maximum injury, expressed as a necrotic effect, was observed about a month after treatment. Regrowth in this treatment occurred about 5 to 6 weeks after treatment. Bromacil at 4#/A was the most phytotoxic to nutsedge on the dates of evaluation. However, D-732 was not much different than bromacil, and by observation D-767 appeared to be less effective than bromacil and D-732, but it was better than amitrole in the long term observations.

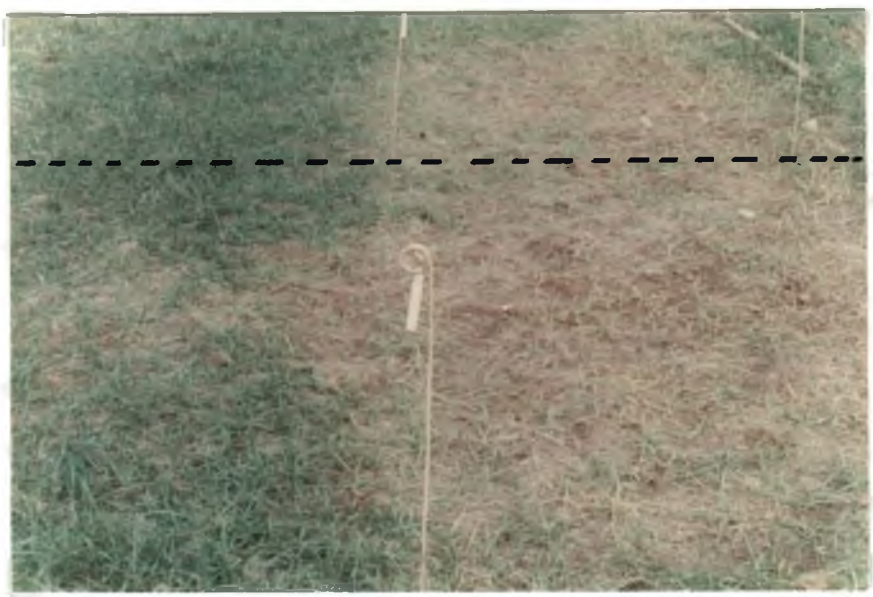

FIGURE 4. FRONT-BROMACIL 4 LBS/A 16 WEEKS AFTER FIRST APPLICATION (LEFT) AND SECOND APPLICATION MADE AT 9 WEEKS AFTER FIRST APPLICATION (RIGHT), BACK-BROMACIL 2 LBS/A 16 WEEKS AFTER FIRST APPLICATION (LEFT) AND SECOND APPLICATION MADE AT 9 WEEKS AFTER FIRST APPLICATION (RIGHT). EXPERIMENT NO. 3 (PHOTOGRAPH TAKEN ON NOVEMBER 25, 1966)

CHECK AMITROLE

FIGURE 5. AMITROLE 8 LBS/A 5 WEEKS AFTER LAST TREATMENT EXPERIMENT NO. 3 (PHOTOGRAPH TAKEN ON APRIL 8, 1967)

Experiment No. 4

This experiment was conducted to compare the results of the translocated herbicides on nutsedge at the Manoa Campus Farm (Experiment 3) to similar treatments at the Waimanalo Experiment Station. The compounds, concentrations (except the lower concentration of bromacil), and volume of the spray per acre were the same as these used in Experiment 3. The results are contained in Table IV.

TABLE IV. RESPONSE OF POST-EMERGENCE HERBICIDES TO NUTSEDGE, WAIMANALO EXPERIMENT STATION EXPERIMENT NO. 4[1]

Treatment lbs active/acre	No. of plants per square foot	
	1st application 50 da[2] (Feb. 19)	2nd application 40 da (Apr. 2)
1. Aromatic oil 55AR 80 gpa	40.8	55.8
2. D-732 4#	28.0	26.8
3. D-767 4#	30.3	22.8
4. Bromacil 4#	24.0	23.0
5. Amitrole 8# + X-77 .2% (v/v)	16.3	22.3
D(5% level)	10.3	7.51

[1] Herbicides applied Dec. 31, 1966 and Feb. 20, 1967, respectively.

[2] No. of days after treatment.

It can be seen that aminotriazole gave the best results in the Feb. 29 evaluation, and even in the final evaluation it gave control equal to that of the uracil compounds (Table IV). The results for April 2 should be treated with caution because a heavy rain on March 7, 1967 of 4.6 inches may have caused lateral movement of the herbicides. However, the high nutsedge population in the aromatic oil treatment indicates that lateral movement was not extensive.

Experiment No. 5

This experiment was initiated at the Manoa Campus Farm to evaluate the effectiveness of pre-emergence and soil-incorporated herbicides on nutsedge control. Since the diverse group of compounds required differing cultural methods of application, statistical analyses were computed for groups of compounds which received similar treatment.

TABLE V. RESPONSE OF PREEMERGENCE AND SOIL-INCORPORATED PREPLANTING HERBICIDES TO NUTSEDGE, MANOA CAMPUS FARM EXPERIMENT NO. 5[1/]

Treatment lbs active/acre	No. of plants per square foot					
	Aug 19	Sept 30	Nov 8	Dec 11	Feb 5	Apr 5
1. Check (cultivated)	34.5(14)[2/]	46.7(31)	74.3(35)	76.3(70	89.0(124)	95.3(42)
2. EPTC 6# (incorp)	1.3	15.0(56	5.3	29.7	37.0	16.7
3. R-1856 10# (incorp)	3.3	8.0	1.7	6.7	29.7	11.3
D(5% level)[3/]	7.03	7.71	7.82	6.40	16.03	12.30
4. Dichlobenil 6# (incorp)	12.0(14)	0.3(31	1.7(70)	3.3(103)	6.0(159)	5.0(42)
5. R-7465 6# (incorp)	25.7	12.3	--	--	--	--
6. CP 50144 4# (incorp)	19.3	27.6	--	--	--	34.0
7. U-22,326 6# (preemergence)	--	--	--	--	--	61.0

[1/] Herbicides applied on Aug. 5, 1966 (EPTC, R-1856, dichlobenil, R-7465, CP 50144), Aug. 30 (R-7465, dichlobenil, CP 50144), Oct. 4 (EPTC, R-1856), and Feb. 22, 1967 (EPTC, R-1856, dichlobenil, CP 50144, U-22,326).

[2/] No. of days since last treatment.

[3/] Statistical analysis completed only for treatments 1 to 3.

Dichlobenil appeared to be the best among the preplant herbicides (Table V). Two applications at 3 weeks intervals of dichlobenil at 6#/A gave good control of nutsedge over a period of 3 months. R-1856 at 10#/A was found to be more effective than EPTC at 6#/A. Good control for a period of 2 months was obtained with a single application of R-1856 at the 10#/A rate. R-7465, CP 50144, and U-22,326 did not provide satisfactory control of nutsedge.

FIGURE 6. DICHLOBENIL 6#/A, 45 DAYS AFTER LAST TREATMENT, EXPERIMENT NO. 5 (PHOTOGRAPH TAKEN ON APRIL 8, 1967)

TRANSLOCATION STUDIES IN THE GREENHOUSE

Experiment No. 6

This experiment was conducted in the greenhouse at the Manoa Campus Farm to study the translocation of paraquat applied at different times during the day. Five microliters of C^{14}-paraquat (.01$\mu c/\mu l$) were applied on the 3th youngest leaf and harvests of the plants for processing were made at 6, 12, 24, and 48 hours after treatment. The degree of translocation is presented in Table VI.

TABLE VI. TIME SERIES STUDIES ON TRANSLOCATION OF C^{14}-PARAQUAT APPLIED AT VARIOUS TIMES OF DAY IN PURPLE NUTSEDGE

Time of Application	Conditions at Time of Application	Time Series (hrs)	Translocation in the leaf[1]/ Acropetal Ave	Basipetal Ave
Morning (9:00 AM)	Light - 2000 fc	6	2.5[2]/	3.5
	Temp - 72°F	12	3.5	3.0
	Rel. Humid. - 72%	24	5.0	1.0
		48	4.5	1.0
Noon (1:00 PM)	Light - 2200 fc	6	1.5	2.0
	Temp - 72°F	12	2.0	1.5
	Rel. Humid. - 73%	24	3.5	3.0
		48	4.5	2.0
Evening (5:00 PM)	Light - 1000 fc	6	5.0	4.0
	Temp - 70°F	12	4.0	3.5
	Rel. Humid. - 80%	24	5.0	5.0
		48	5.0	3.0

[1]/1 - no movement, 2 - 1/4 of the leaf length, 3 - 1/2, 4 - 3/4, 5 - complete movement.

[2]/Each value is the result of an average of two autoradiographs.

It can be seen in the 6 and 12 hour series that the evening treatment resulted in more translocation of paraquat both in an acropetal and basipetal direction than the morning and noon treatments. The results among the 24 and 48 hour series are not greatly different. Movements of paraquat to the pseudo-stem and tuber were not observed in any of the treatments. There were variations in basipetal movement of paraquat, possibly due to variation in the physiological age of the leaves.

Experiment No. 7

This experiment was initiated to study the time series translocation of C^{14}-labeled compounds of paraquat and MSMA applied in the morning, noon, and evening on the 5th youngest leaf. Harvests of the treated plants were made at 2, 4, 8, and 16 days after treatment. The results are contained in Table VII.1.

TABLE VII.1. TIME SERIES STUDIES ON TRANSLOCATION OF C^{14}-PARAQUAT APPLIED AT VARIOUS TIMES OF DAY IN PURPLE NUTSEDGE

Time of Application	Conditions at Time of Application	Time Series (days)	Translocation in the leaf		Remarks
			Acropetal	Basipetal	
Morning (9:00 AM)	Light - 2000 fc	2	4.0	1.0	
	Temp - 74°F	4	4.5	4.5	Translocated to another leaf in 1 plant
	Rel. Humid. - 75%	8	5.0	1.0	
		16	5.0	2.0	
Noon (1:00 PM)	Light - 4000 fc	2	5.0	4.0	
	Temp - 81°F	4	3.5	1.0	
	Rel. Humid. - 72%	8	4.5	1.0	
		16	4.0	2.0	
Evening (5:00 PM)	Light - 100 fc	2	3.0	1.0	
	Temp - 74°F	4	3.5	1.0	
	Rel. Humid. - 81%	8	3.0	1.0	
		16	5.0	2.5	

1/ 1 - no movement, 2 - 1/4 of the leaf length, 3 - 1/2, 4 - 3/4, and 5 - complete movement.

2/ Each value is the result of an average of two autoradiographs.

In contrast to Experiment 6, the paraquat evening treatment did not show better translocation when compared with the morning and noon applications. There might be some factors which interfered with the experiment, possibly due to fluctuation of natural light intensity. Also, the nutsedge plants used in Experiment 7 were 2 weeks older than the plants used in Experiment 6 and they had much larger leaves.

TABLE VII.2. TIME SERIES STUDIES ON TRANSLOCATION OF C^{14}-MSMA APPLIED AT VARIOUS TIMES OF DAY IN PURPLE NUTSEDGE

Time of Application	Conditions at Times of Application	Time Series (days)	Translocation in the Leaf[1/] Acropetal	Basipetal	Remarks
Morning (9:00 AM)	Light - 2000 fc	2	5.0[2/]	3.5	
	Temp - 74°F	4	5.0	3.5	
	Rel. Humid. - 75%	8	5.0	4.0	Translocated to flower in 1 plant
		16	5.0	1.5	
Noon (1:00 PM)	Light - 4000 fc	2	5.0	4.0	Translocated to another leaf in 1 plant
	Temp - 81°F	4	3.0	4.5	Translocated to another 2 leaves in 1 plant
	Rel. Humid. - 72%	8	3.5	3.5	Translocated to another 2 leaves in 1 plant
		16	1.0	5.0	Translocated to another 2 leaves in 2 plants
Evening (5:00 PM)	Light - 100 fc	2	1.0	3.0	Translocated to another 2 leaves in 1 plant
	Temp - 74°F	4	4.0	2.0	
	Rel. Humid.- 81%	8	5.0	3.5	Translocated to another leaf in 1 plant
		16	2.5	2.0	

[1/] 1 - no movement, 2 - 1/4 of the leaf length, 3 - 1/2, 4 - 3/4, 5 - complete movement.

[2/] Each value is the result of an average of two.

In contrast to paraquat, MSMA translocation was increased when applied in the morning and at noon (Table VII.2). There was a greater translocation of MSMA to other leaves in the morning and noon applications. It is surprising that the translocation to the other leaves (usually younger) or to the upper part of peduncle was observed in two or three plants in the morning treatment, but only one was shown on the autoradigraph. It was also observed that young and healthy leaves respond to the chemical more than the older leaves. Translocation of MSMA to the pseudo-stem was observed in only one plant in the noon treatment of the 16 day series. As with paraquat, no movement of MSMA to the tuber was observed. However, the possibility of this happening in future experiments is not rejected, especially when the field results are considered. One reason for the lack of translocation into the tuber may have been the very low specific activity of the labeled chemical (less than .002 μc/μl) and the application of only 5 μl per plant.

FIGURE 7. TRANSLOCATION OF C^{14}-MSMA 4 DAYS AFTER EVENING TREATMENT (FAR LEFT), C^{14}-MSMA 16 DAYS AFTER NOON TREATMENT (MIDDLE), AND C^{14}-PARAQUAT 16 DAYS AFTER EVENING TREATMENT (FAR RIGHT), EXPERIMENT NO. 7.

MSMA
Evening treatment
4 days

MSMA
Noon treatment
16 days

Paraquat
Evening treatment
16 days

DISCUSSION

In the contact herbicide experiments, it was found that successive applications of MSMA resulted in about thirty per cent reduction in the nutsedge population over a period of 8 months (Tables I.1, I.2). Even though MSMA did not give satisfactory results in controlling nutsedge, the chemical was the most promising when compared to DSMA, DMAA, paraquat, and aromatic oil. Time of application was very important in using MSMA. Field applications in the morning or at noon gave much better control than in the evening. These time difference results agree with the company research as stated by Widiger (1966), namely that sunlight appears to be important for maximum effectiveness with the arsonates. The effect of light on the activity of the arsonates can be seen from the results at the Manoa Campus (Table I.2). It is possible that light affects chemical penetration.

Translocation studies in the greenhouse with C^{14}-MSMA showed that the noon application produced more translocation into untreated leaves than in the evening application. Even though movement to the other leaves occurred in evening treatment, it was very slight. It seemed that darkness restricts penetration more than translocation, and the stage of growth appeared to be another factor influencing the penetration. The experiments at the Waimanalo Experiment Station show that the effect of light was not as striking as at the Manoa Campus Farm. This might be explained by the fact that the applications were made in partly cloudy weather at Waimanalo (Appendix Table VI).

Another result that should not be overlooked is the phytotoxicity of DSMA. This chemical was replaced by DMAA in the last two applications at the Waimanalo Experiment Station because of its ineffectiveness in nutsedge control. When careful investigation was made of this chemical at the Manoa Campus Farm, it was found that the chemical was effective in the control of nutsedge. Nutsedge populations in the DSMA treatment were comparable to MSMA; therefore it should be noted that DSMA was equal to MSMA at one of two test locations. The weather data contained in Appendix Table VI show that more sunshine was available at treatment time at the Manoa Campus where more effective control was obtained. This evidence shows that the effect of light on the activity of the arsonates should receive more consideration in future experiments.

DMAA resulted in slightly less nutsedge control than MSMA and although the differences were not statistically significant, the activity of DMAA should be considered for additional experimentation. Holt et al. (1967) found that the failure of nutsedge to sprout after repeated applications was not directly related to the arsenic content in nutsedge tubers. He suggested that tuber lethality following repeated treatment with arsenicals may be due to depletion of the food reserves and/or bud supply from increased sprouting and not to the accumulation of a specific level of arsenic in the tubers. From the results observed in Experiments 1a, 1b, 2a, and 2b in which many chemicals were tested, it can be said that all of them could have resulted in the depletion of food reserves and increased sprouting, but the long term effect under field conditions showed that the

arsonates turned out to be better than the other herbicides. Therefore, it may have been a more complicated physiological action than a simple depletion of food reserves.

The phytotoxic effects of paraquat are short-lived. Generally it is slightly better or about the same as aromatic oil after a period of one month. Paraquat applications in the evening produced better results than the morning and noon applications. This may have been the result of more uptake and translocation under high humidity conditions as suggested by Brian (1966). The translocation studies showed that paraquat applications in the evening (5:00 to 6:00 PM) resulted in more translocation than in the morning and noon applications. Wood and Gosnell (1966) also found that the extent of translocation of paraquat-C^{14} in nutsedge (Cyperus rotundus) was much greater when 24 hours of darkness followed treatment than when the treatments were applied at 6:00 AM, 10:00 AM, and 2:00 PM. Slade and Bell (1965) reasoned that the enhancement of the amount of paraquat transported from the treated leaves which occurs when treated plants are kept in darkness for a period following treatment and then exposed to light, is probably due to the greater movement into the xylem through undamaged tissues which are kept in the dark. Once the chemical has been absorbed into treated leaves, light-induced damage is required for significant movement through the rest of the plant. Another reason for penetration of paraquat in darkness may be the prolonged retention of the chemical on the tissue surface without degradation. Slade (1966) found that degradation of paraquat was not observed in the dark, and only occurred to a significant extent in

daylight in summer. In the field (Experiments 1 and 2) nutsedge regrowth in the evening treatment developed slowly compared to the morning or noon treatment and it is suspected from the regrowth pattern of the nutsedge that paraquat might have translocated into the tubers. The results of translocation studies (Experiments 6 and 7) showed that only small amounts of paraquat moved basipetally and it was not found in the tubers after 16 days. Wood and Gosnell (1966) also reported this effect; however, a trace of the chemical might be enough for temporarily retarding the regrowth development of nutsedge.

It should be noted that the methanearsonate and paraquat studies were conducted under full sunlight. The possibility exists that the use of paraquat in the partial shade of fruit orchards may provide more satisfactory control. Nutsedge does not grow well under shade conditions and this may make the plants more susceptible to herbicide injury. Also, the shade conditions may enhance the activity of paraquat comparable to that of an evening application.

In the translocated herbicide experiments it was found that bromacil and D-732 at 4#/A gave the best control. D-767 produced a slightly less degree of nutsedge control than bromacil and D-732, although the differences were not significant. D-732 and D-767 are expected to play an increasingly important role in the control of nutsedge in some tolerant crops as sugar cane, mint and citrus. Overall, amitrole was not as effective as the uracils. A shorter interval of repeated applications of amitrole might be required for the control of nutsedge. Amitrole and bromacil are highly phytotoxic to several crops. Bromacil was recently registered for use with

pineapple in Hawaii.

The soil incorporation of dichlobenil resulted in superior control followed by R-1856 and EPTC. R-7456, CP 50144 and U-22,326 were not effective in controlling nutsedge. It was found that the last application of EPTC, R-1856 and dichlobenil did not produce satisfactory results. Unfortunately there was a rainfall after the application that resulted in an inch or more of water. Gray and Weierch (1965) reported that there is a greater loss of EPTC in moist soil than in dry soil. Although dichlobenil gave a long period of control, the compound is toxic to several horticultural crops. This compound is registered for use in mango and avocado orchards and with woody ornamentals in the United States, but field performance data are not readily available. R-1856 is not presently registered for use in cultivated crops. EPTC is registered for use with beans, corn, asparagus, and carrots. It is phytotoxic to several other vegetables if they are sown or planted immediately after treatment.

SUMMARY

The effectiveness of chemicals for nutsedge control was evaluated at the Manoa Campus Farm and the Waimanalo Experiment Station from April 1966 until the end of April 1967. The studies included field experiments and greenhouse translocation studies. The field experiments were divided into post-emergence herbicides and pre-emergence and preplant herbicides. The post-emergence herbicides used in the studies were aromatic oil, MSMA, DSMA, DMAA, paraquat, D-732, D-767, bromacil and amitrole. The pre-emergence herbicides were CP 50144, U-22,326 and the preplant herbicides were EPTC, R-1856, R-7465, and dichlobenil. The results of the studies can be summarized as follows:

1. MSMA was found to be the most effective for nutsedge control for successive applications of the contact herbicides. The population reduction of nutsedge in the MSMA treatments was about one-third of the non-treated check after 3 applications were made over an eight month period. However, in terms of the degree of control, the results were not entirely satisfactory.
2. The results obtained with DSMA require additional studies as the compound gave comparable results to MSMA at the Manoa Campus Farm, but significantly less nutsedge control than MSMA at the Waimanalo Experiment Station.
3. DMAA appeared to be a promising compound for future nutsedge control studies based on the experimental results.

4. Paraquat gave comparable control to aromatic oil (check) in the long term effects and this was not considered satisfactory.
5. There were interactions between paraquat and MSMA and the time of application. Evening applications (5:00-6:00 PM) of paraquat resulted in slower regrowth than morning (8:00-9:00 AM) or noon (1:00 to 2:00 PM) applications. Paraquat-C^{14} translocation studies showed that there was slightly more basipetal movement of the herbicides in the evening treatments than in either morning or noon treatments. MSMA was found to be less phytotoxic to nutsedge when applications were made in the evening than in the morning or afternoon.
6. Bromacil and D-732 showed the most effective control among the translocated herbicides. However, D-767 was almost as effective as bromacil or D-732. All the uracil compounds were slow acting but they did produce a long term control. Amitrole gave a shorter period of control and required more frequent applications.
7. Dichlobenil gave the most satisfactory control among the pre-plant and pre-emergence herbicides. Good control was obtained with two applications of 6#/A dichlobenil for a period of 5 months. R-1856 and EPTC resulted in good nutsedge control for a period of 4 to 5 weeks. R-7456, CP 50144, and U-22,326 did not provide satisfactory nutsedge control under the ecological and edaphic conditions of the Manoa Campus Farm experiment.

APPENDIX

APPENDIX TABLE I.1. ANALYSIS OF VARIANCE OF NUTSEDGE RESPONSE TO CONTACT HERBICIDES EVALUATED ON AUGUST 19, 1966. EXPERIMENT NO. 1a, TABLE I.1

Sources of Variation	Degrees of freedom	Sum of Squares	Mean Square
Block	2	67.73	
Treatments:	(4)		
Check vs. herbicides	1	601.67	601.67**
Among herbicides	3	232.33	77.44*
Error	8	111.60	13.95

*Significant

**Highly significant

APPENDIX TABLE I.2. ANALYSIS OF VARIANCE OF NUTSEDGE RESPONSE TO CONTACT HERBICIDES EVALUATED ON NOVEMBER 8, 1966. EXPERIMENT NO. 1a, TABLE I.1

Source of Variation	Degrees of freedom	Sum of Squares	Mean Square
Block	2	117.73	
Treatments:	(4)		
Check vs. herbicides	1	41.67	41.67
Among herbicides	3	480.33	160.11**
Error	8	71.60	8.95

**Highly significant

APPENDIX TABLE I.3. EFFECT OF TIME OF APPLICATION TO NUTSEDGE RESPONSE TO THE HERBICIDES EVALUATED ON DECEMBER 17, 1966. EXPERIMENT NO. 1b, TABLE I.2

	No. of plants/sq. ft.			
	Rep 1	Rep 2	Rep 3	Ave
Check (Aromatic Oil 55 AR) 80 gpa				
Noon (1:00-2:00 PM)	26	28	38	30.7
Evening (5:00-6:00 PM)	23	26	31	26.7
MSMA 6# + X-77 .2%				
Noon	37	33	35	35.0
Evening	48	39	30	39.0
DSMA 6# + X-77 .2%				
Noon	34	37	26	32.3
Evening	38	44	32	38.0
Paraquat 1# + X-77 .2%				
Noon	18	16	18	17.3
Evening	13	11	10	11.3

APPENDIX TABLE I.4. EFFECT OF TIME OF APPLICATION TO NUTSEDGE RESPONSE TO THE HERBICIDES EVALUATED ON FEBRUARY 5, 1967. EXPERIMENT NO. 1b, TABLE I.2

	No. of plants/sq. ft.			
	Rep 1	Rep 2	Rep 3	Ave
Check (Aromatic Oil 55AR) 80 gpa				
Noon (1:00-2:00 PM)	100	82	90	90.7
Evening (5:00-6:00 PM)	95	82	76	84.3
MSMA 6# + X-77 .2%				
Noon	105	93	61	86.3
Evening	101	80	50	77.0
DSMA 6# + X-77 .2%				
Noon	90	92	65	82.3
Evening	102	80	61	81.0
Paraquat 1# + X-77 .2%				
Noon	109	112	68	96.3
Evening	106	82	55	81.0

APPENDIX TABLE I.5. EFFECT OF TIME OF APPLICATION TO NUTSEDGE RESPONSE TO THE HERBICIDES EVALUATED ON MARCH 5, 1967. EXPERIMENT NO. 1b, TABLE II.1

	No. of plants/sq. ft.			
	Rep 1	Rep 2	Rep 3	Ave.
Check (Aromatic Oil 55AR (80 gpa				
Noon (1:00-2:00 PM)	59	57	63	59.7
Evening (5:00-6:00 PM)	55	52	49	52.0
MSMA 6# + X-77 .2%				
Noon	40	37	40	39.0
Evening	60	53	48	53.7
DSMA 6# + X-77 .2%				
Noon	36	40	32	36.0
Evening	53	56	41	50.0
Paraquat 1# + X-77 .2%				
Noon	45	48	41	44.7
Evening	18	23	25	22.0

APPENDIX TABLE I.6. EFFECT OF TIME OF APPLICATION TO NUTSEDGE RESPONSE TO HERBICIDES EVALUATED ON APRIL 2, 1967. EXPERIMENT NO. 1b, TABLE II.1

	No. of plants/sq. ft.			
	Rep 1	Rep 2	Rep 3	Ave
Check (Aromatic Oil 55AR) 80 gpa				
Noon (1:00-2:00 PM)	90	85	83	86.0
Evening (5:00-6:00 PM)	78	80	76	78.0
MSMA 6# + X-77 .2%				
Noon	67	58	48	57.7
Evening	88	76	76	80.0
DSMA 6# + X-77 .2%				
Noon	65	63	44	58.0
Evening	80	85	76	80.3
Paraquat 1# + X-77 .2%				
Noon	98	95	78	90.3
Evening	82	84	75	80.3

APPENDIX TABLE II.1. ANALYSIS OF VARIANCE OF NUTSEDGE RESPONSE TO HERBICIDES APPLIED AT DIFFERENT TIMES OF THE DAY, EVALUATED ON OCTOBER 24, 1966. EXPERIMENT NO. 2a

Sources of Variation	Degrees of freedom	Sum of Squares	Mean Square
Main plots:			
Herbicides	3	439.89	146.63**
Blocks	3	181.23	60.41*
Main plot error	9	136.19	15.13
Sub Plots:			
Time of Application	2	281.29	140.65**
Time x herbicide	6	201.30	33.55**
Sub-plot error	24	124.08	5.17

*Significant
**Highly significant

APPENDIX TABLE II.2. ANALYSIS OF VARIANCE OF NUTSEDGE RESPONSE TO HERBICIDES APPLIED AT DIFFERENT TIMES OF THE DAY, EVALUATED ON NOVEMBER 7, 1966. EXPERIMENT NO. 2a

Sources of Variation	Degrees of freedom	Sum of Squares	Mean Square
Main plots:			
Herbicides	3	1112.17	370.72
Blocks	3	693.17	231.06
Main plot error	9	1050.83	116.74
Sub Plots:			
Time of Application	2	142.05	71.03
Time x herbicide	6	265.70	44.28
Sub-plot error	24	504.50	20.93

APPENDIX TABLE II.3. ANALYSIS OF VARIANCE OF NUTSEDGE RESPONSE TO HERBICIDES APPLIED AT DIFFERENT TIMES OF THE DAY, EVALUATED ON NOVEMBER 22, 1966. EXPERIMENT NO. 2a

Sources of Variation	Degrees of freedom	Sum of Squares	Mean Square
Main plots:			
Herbicides	3	847.09	282.36 NS
Blocks	3	821.09	273.70 NS
Main plot error	9	730.41	81.16
Sub Plots:			
Time of application	2	74.55	37.28*
Time x herbicide	6	390.28	65.05**
Sub-plot error	24	258.56	10.77

*Significant
**Highly Significant

APPENDIX TABLE II.4. ANALYSIS OF VARIANCE OF NUTSEDGE RESPONSE TO HERBICIDES APPLIED AT DIFFERENT TIMES OF THE DAY, EVALUATED ON JANUARY 25, 1967. EXPERIMENT NO. 2a

Sources of Variation	Degrees of freedom	Sum of Squares	Mean Square
Main Plots:			
Herbicides	3	1128.50	376.17
Blocks	3	1255.84	418.61
Main plot error	9	1420.00	157.78
Sub-plot			
Time of application	2	6.17	3.09
Time x herbicide	6	53.50	8.92
Sub-plot error	24	413.66	17.24

APPENDIX TABLE II.5. ANALYSIS OF VARIANCE OF NUTSEDGE RESPONSE TO HERBICIDES APPLIED AT DIFFERENT TIMES OF THE DAY, EVALUATED ON FEBRUARY 20, 1967. EXPERIMENT NO. 2b

Sources of Variation	Degrees of freedom	Sum of Squares	Mean Square
Main Plots:			
Herbicides	3	4210.17	1403.39**
Blocks	3	560.83	186.94
Main plot errors	9	534.33	59.37
Sub Plots:			
Time of application	2	35.38	17.69
Time x herbicide	6	1781.45	296.91**
Sub-plot error	24	669.84	27.91

**Highly Significant

APPENDIX TABLE II.6. ANALYSIS OF VARIANCE OF NUTSEDGE RESPONSE TO HERBICIDES APPLIED AT DIFFERENT TIMES OF THE DAY, EVALUATED ON MARCH 31, 1967. EXPERIMENT NO. 2b

Sources of Variation	Degrees of freedom	Sum of Squares	Mean Square
Main Plots:			
Herbicides	3	2965.08	988.36**
Blocks	3	1514.75	504.92
Main plot error	9	952.09	105.79
Sub Plot:			
Time of application	2	222.88	111.44
Time x herbicide	6	1260.29	210.05**
Sub-plot error	24	824.16	34.34

**Highly Significant

APPENDIX TABLE II.7. ANALYSIS OF VARIANCE OF NUTSEDGE RESPONSE TO HERBICIDES APPLIED AT DIFFERENT TIMES OF THE DAY, EVALUATED ON APRIL 30, 1967. EXPERIMENT NO. 2b

Sources of Variation	Degrees of freedom	Sum of Squares	Mean Square
Main Plots:			
Herbicides	3	4403.84	1467.95**
Blocks	3	304.67	101.56
Main plot error	9	1199.83	133.31
Sub Plots:			
Time of application	2	521.30	260.65*
Time x herbicide	6	2913.03	485.51**
Sub-plot error	24	1183.00	49.29

*Significant
**Highly Significant

APPENDIX TABLE III.1. ANALYSIS OF VARIANCE OF RESPONSE OF HERBICIDES TO NUTSEDGE EVALUATED ON NOVEMBER 8, 1966. EXPERIMENT NO. 3

Sources of Variation	Degrees of freedom	Sum of Squares	Mean Square
Block	2	99.44	48.22
Treatment	5	679.11	135.82**
Error	10	230.22	23.02

**Highly Significant

APPENDIX TABLE III.2. ANALYSIS OF VARIANCE OF RESPONSE OF HERBICIDES TO NUTSEDGE EVALUATED ON FEBRUARY 5, 1967. EXPERIMENT NO. 3

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Block	2	175.00	87.50
Treatment	5	11573.17	2314.63**
Error	10	750.33	75.03

**Highly Significant

APPENDIX TABLE III.3. ANALYSIS OF VARIANCE OF RESPONSE OF HERBICIDES TO NUTSEDGE EVALUATED ON APRIL 30, 1967. EXPERIMENT NO. 3

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Block	2	70.11	35.06
Treatment	5	18617.11	3723.42**
Error	10	245.89	24.59

**Highly Significant

APPENDIX TABLE IV.1. ANALYSIS OF VARIANCE OF RESPONSE OF HERBICIDES TO NUTSEDGE EVALUATED ON FEBRUARY 19, 1967 EXPERIMENT NO. 4

Sources of Variation	Degrees of freedom	Sum of Squares	Mean Square
Block	3	97.35	32.45
Treatment	4	1286.30	321.57**
Error	12	248.90	20.74

**Highly Significant

APPENDIX TABLE IV.2. ANALYSIS OF VARIANCE OF RESPONSE OF HERBICIDES TO NUTSEDGE EVALUATED ON APRIL 2, 1967 EXPERIMENT NO. 4

Sources of Variation	Degrees of freedom	Sum of Squares	Mean Square
Block	3	281.80	93.93
Treatment	4	3059.20	764.80**
Error	12	133.20	11.10

**Highly Significant

APPENDIX TABLE V.1. ANALYSIS OF VARIANCE OF PREEMERGENCE AND PREPLANTING HERBICIDES TO NUTSEDGE EVALUATED ON AUGUST 19, 1966 EXPERIMENT NO. 5

Sources of Variation	Degrees of freedom	Sum of Squares	Mean Square
Block	2	6.89	3.45
Treatments	(2)		
Herbicides x check	1	3813.56	3813.56**
Among herbicides	1	6.00	6.00
Error	4	38.44	9.61

**Highly Significant

APPENDIX TABLE V.2. ANALYSIS OF VARIANCE OF PREEMERGENCE AND PREPLANTING HERBICIDES TO NUTSEDGE EVALUATED ON SEPTEMBER 30, 1966 EXPERIMENT NO. 5

Sources of Variation	Degrees of freedom	Sum of Squares	Mean Square
Block	2	48.22	24.11
Treatments	(2)		
Herbicides x check	1	2473.39	2473.39**
Among herbicides	1	73.50	73.50
Error	4	84.44	21.11

**Highly Significant

APPENDIX TABLE V.3. ANALYSIS OF VARIANCE OF PREEMERGENCE AND PREPLANTING HERBICIDES TO NUTSEDGE EVALUATED ON NOVEMBER 8, 1966 EXPERIMENT NO. 5

Sources of Variation	Degrees of freedom	Sum of Squares	Mean Square
Block	2	96.89	48.45
Treatments	(2)		
Herbicides x check	1	10034.72	10034.72**
Among herbicides	1	20.17	20.17
Error	4	149.11	37.28

**Highly Significant

APPENDIX TABLE V.4. ANALYSIS OF VARIANCE OF PREEMERGENCE AND PREPLANTING HERBICIDES TO NUTSEDGE EVALUATED ON DECEMBER 11, 1966 EXPERIMENT NO. 5

Sources of Variation	Degrees of freedom	Sum of Squares	Mean Square
Block	2	76.22	38.11
Treatments	(2)		
Herbicides x check	1	6766.72	6766.72**
Among herbicides	1	793.50	793.50**
Error	4	31.78	7.94

**Highly Significant

APPENDIX TABLE V.5. ANALYSIS OF VARIANCE OF PREEMERGENCE PREPLANTING HERBICIDES TO NUTSEDGE EVALUATED ON FEBRUARY 5, 1967 EXPERIMENT NO. 5

Sources of Variation	Degree of freedom	Sum of Squares	Mean Square
Block	2	402.89	201.45
Treatments	(2)		
Herbicides x check	1	6197.56	6197.56**
Among herbicides	1	80.66	80.66
Error	4	199.78	49.95

**Highly significant

APPENDIX TABLE V.6. ANALYSIS OF VARIANCE OF PREEMERGENCE AND PREPLANTING HERBICIDES TO NUTSEDGE EVALUATED ON APRIL 5, 1967 EXPERIMENT NO. 5

Sources of Variation	Degrees of freedom	Sum of Squares	Mean Square
Block	2	308.22	154.11
Treatments	(2)		
Herbicides x check	1	13230.22	13230.22**
Among herbicides	1	42.67	42.67
Error	4	117.78	29.45

**Highly significant

APPENDIX TABLE VI. WEATHER CONDITION AT SPRAY TIME

Date	Time	TEMPERATURE Air °F	TEMPERATURE Soil °F	Soil Moisture (%)	Wind (mph)	Cloud Over
Manoa Campus Farm						
Aug 5'66	2:00-4:30 PM	88	92	--	4-6	Sunny
Aug 30	1:00-3:00 PM	86	90	--	0-2	Sunny
Oct 4	11:30 AM-2:00 PM	86	90	25	5-8	Sunny
Nov 20	2:00-3:30 PM	74	81	28	0-3	Cloudy
Nov 21	Noon 1:00-2:00 PM	82	84	28	2-4	Slightly cloudy
	Evening 5:00-6:00 PM	76	82		0-2	"
Feb 13'67	Noon	78	80	30	5-7	Partly cloudy
	Evening	74	78		8-10	Cloudy
Feb 22	3:00-4:30 PM	78	78	32	8-10	Sunny

APPENDIX TABLE VI. (Continued) WEATHER CONDITION AT SPRAY TIME

Date	Time	TEMPERATURE Air °F	TEMPERATURE Soil °F	Soil Moisture (%)	Wind (mph)	Cloud Over
Waimanalo Experimental Farm						
Oct 13'66	Morning 8:00-9:00 AM	82	78	28	7-9	Cloudy
	Noon 1:00-2:00 PM	86	88		8-10	"
	Evening 5:00-6:00 PM	83	78		8-10	"
Nov 13	Morning	82	76	36	3-5	Cloudy
	Noon	84	86		0-3	"
	Evening	76	82		0	"
Dec 31	9:00-12:00 AM	79	81	36	8-10	Cloudy
Jan 26'67	Morning	78	74	38	1-3	Cloudy
	Noon	74	76		3-5	"
	Evening	71	76		1-3	"
Feb 20	1:00-2:30 PM	80	80	38	8-10	Cloudy
Mar 31	Morning	82	81	32	8-10	Partly cloudy
	Noon	82	86		6-8	"
	Evening	70	80		1-3	Cloudy + slight rain for 10 min after treatment

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